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Fabrication and characterization of terahertz anisotropic anti-rod dimer planar metamaterials

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Summary

In this work we describe the fabrication and characterization of free-standing membranes with thick anti-rod dimers metamaterials for terahertz waves. Two different designs with parallel and V-shape anti-rods were analysed. Even though both structures consists of simple elements, namely anti-rod dimers, they reveal interesting birefringent and dichroic transmission properties.

Introduction

Terahertz waves have received a lot of attention in recent years due to their application in variety of fields as e.g. security, sensing, imaging, communication and spectroscopy. Although there is a broad range of applications where terahertz radiation plays an important role, there is still a lack of THz-optic components to exploit the full potential of terahertz radiation.

Metamaterials are artificially made materials with exceptional properties as e.g. negative refractive index, electromagnetic invisibility, focusing by flat surfaces and perfect absorbers. The ability to modify the electromagnetic response makes metamaterials obvious candidate to be integrated in THz-optic components [1].

Design and Fabrication

Usually the modified electromagnetic response is achieved by metallic split ring resonators, U-shapes, omega-shapes etc., which are rather complex in their design. Here we present a simple design of anti-rod dimers based on the work by S. V. Zhukovsky *et. al.* [2].

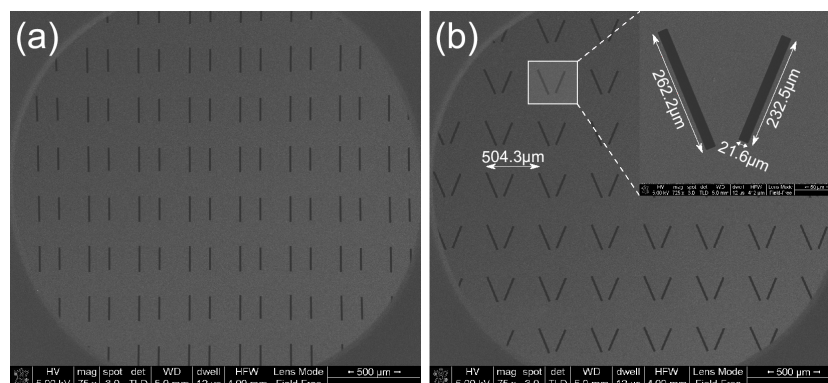


Fig 1. Scanning electron images of anti-rod dimers metamaterials. (a) Parallel design and (b) V-shape design of anti-rod samples. Inset displays the sizes of the elements.

The anti-rod dimers are slits in the 2 μm thick nickel membrane. The desired pattern of the nickel membrane was achieved by selective electrochemical growth of nickel on top of a 50 nm thick gold layer. The full fabrication flow is presented in [3]. The fabricated samples are shown in Fig. 1. Both samples had a period of approximately 500 μm . Even though the membranes are only 2 μm thick, it was possible to fabricate samples of 8 mm x 8 mm in size.

Characterization

The anti-rod dimers were characterized by a T-Ray 4000 terahertz time-domain spectroscopy system. With a scan rate of 100 Hz it was possible to generate and detect 20.000 waveforms within approximately 4 minutes. The average of all 20.000 waveforms was then used to characterize the transmission behaviour of the anti-rod dimer metamaterials. The transmission spectra, normalized to air, are shown in Fig.2.

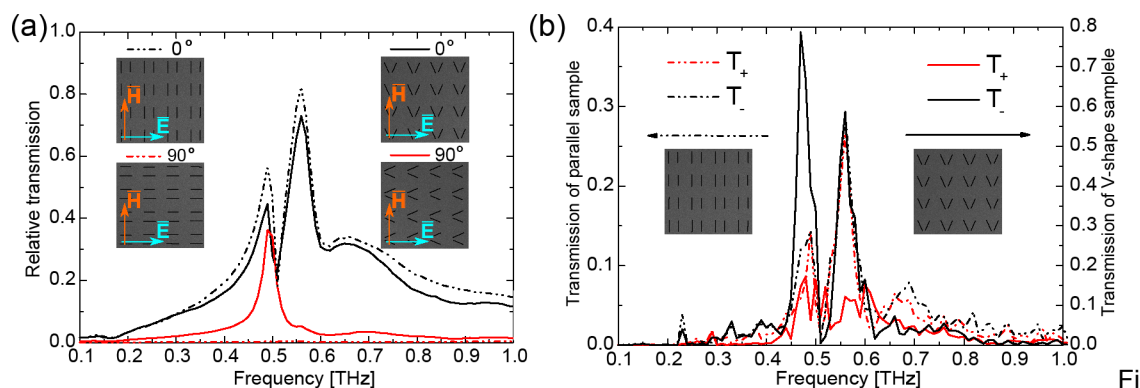


Fig 2. (a) Relative transmission of parallel (dashed line) and V-shaped (solid line) anti-rod dimers metamaterials with sample orientation relative to the electromagnetic field polarization at 0° and 90°. (b) The intensity transmission coefficient of right-handed (T+) and left-handed (T-) circular polarized components for parallel (dashed line) and V-shaped (solid line) designs.

Different behaviour is observed for parallel and V-shape samples when the sample was rotated 90° as shown in Fig. 2(a). At 0° polarization, both samples show similar transmission profiles, namely two transmission bands separated by a transmission dip at 0.51 THz as shown in Fig. 2(a). When rotated to 90°, the transmission of parallel sample drops to approximately zero, while the V-shape display a transmission band at 0.49 THz. The intensity transmission coefficient of right-handed (T+) and left-handed (T-) circular polarized components shown in Fig. 2(b) reveals dichroism behaviour of the V-shape sample, due to the chiral geometry of the unit cell of the V-shape sample. While T+ is highly inhibited, T- experiences two transmission peaks. As expected, no circular dichroism was observed for the parallel sample. The retrieval procedure of circular transmission components from the linear polarization basis is described by R. Singh *et. al.* [4].

References

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